TECHNOLOGY DEMONSTRATION REPORT

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Fixatives Applied to Hot Cell Facilities via Remote Sprayer Platform

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ABSTRACT

The objective of the US Department of Energy Office of Environmental Management's (DOE-EM's) D&D Toolbox Project is to use an integrated systems approach to develop a suite of decontamination & decommissioning (D&D) technologies, a D&D toolbox, that can be readily used across the DOE complex to improve safety, reduce technical risks, and limit uncertainty within D&D operations. Florida International University's Applied Research Center (FIU-ARC) is supporting this initiative by identifying technologies suitable to meet specific facility D&D requirements, assessing the readiness of those technologies for field deployment, and conducting technology demonstrations of selected technologies at FIU-ARC facilities in Miami, Florida. To meet the technology gap challenge for a technology to remotely apply strippable/fixative coatings, FIU-ARC identified and demonstrated of a remote fixative sprayer platform. During this process, FIU-ARC worked closely with the Oak Ridge National Laboratory in the selection of typical fixatives and in the design of a hot cell mockup facility for demonstrations at FIU-ARC. For this demonstration and for future demonstrations, FIU-ARC built a hot cell mockup facility at the FIU-ARC Technology Demonstration/Evaluation site in Miami, Florida.

FIU-ARC selected the International Climbing Machines' (ICM's) Robotic Climber to perform this technology demonstration. The selected technology was demonstrated at the hot cell mockup facility at FIU-ARC during the week of November 10, 2008. Fixative products typically used inside hot cells were investigated and selected for this remote application [1]. The fixatives tested included Sherwin Williams' Promar 200 and DTM paints and Bartlett's Polymeric Barrier System (PBS). The technology evaluation documented the ability of the remote system to spray fixative products on horizontal and vertical concrete surfaces. The technology performance, cost, and health & safety issues were evaluated during this technology demonstration.

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INTRODUCTION

Many facilities slated for decontamination and decommissioning (D&D) across the Department of Energy (DOE) complex pose hazards (radiological, chemical, and structural) which limit, and in many instances prevent, the use of traditional manual techniques. Efficient and safe D&D of the facilities will require the use of remotely operated technologies. In addition, the D&D of a hot cell facility normally requires that each of the hot cells be cleaned and stabilized to allow demolition to occur while maintaining worker radiation exposure as-low-as-reasonably-achievable (ALARA) and without spreading radioactive contamination. One decontamination step usually consists of applying a fixative coating (or similar material) to all hot cell surfaces to hold contamination in place during hot cell demolition. A study on available remote technologies for D&D activities, performed by Florida International University (FIU) and NuVision Engineering (NVE) [2], indicated that there was no remotely operated technology available to meet the need for the remote application of strippable/fixative coatings. This gap between the identified needs and the available technologies is especially critical for hot cell facilities, where physical access is typically very limited and where ALARA and other safety hazards may preclude human entry.

The objective of the D&D Toolbox Project is to use an integrated systems approach to develop a suite of D&D technologies (D&D toolbox) that can be readily used across the DOE complex to reduce technical risks, improve safety, and limit uncertainty within D&D operations. FIU is identifying technologies suitable to meet specific facility D&D requirements, assessing the readiness of those technologies for field deployment, and conducting technology demonstrations of selected technologies at FIU facilities.

To meet the technology gap challenge for a technology to remotely apply strippable/fixative coatings, FIU identified and demonstrated a remote fixative sprayer platform. FIU worked with the Oak Ridge National Laboratory and considered recommendations from the Savannah River Site (SRS) ALARA Center in the selection of typical fixatives [1] and designed a hot cell mockup facility for demonstrations at FIU. FIU built the hot cell mockup facility at the FIU technology demonstration/evaluation site in Miami.

The selected technology was demonstrated at the hot cell mockup facility in Miami. Fixative products typically used inside hot cells were investigated for potential remote application [1]. The technology evaluation documented the ability of the remote system to spray fixative product(s) on horizontal and vertical concrete surfaces. The technology performance, cost, and health & safety issues were evaluated during this technology demonstration.

EXPERIMENTAL

Testing of the ICM climber technology with a custom spray applicator was conducted to demonstrate "proof-of-concept" under conditions similar to those actually found in a DOE hot cell facility. Objects commonly found in hot cells were incorporated into the mockup hot cell during the demonstration and included items such as a work table, ladder, conduit, 50-gallon drum, and a mounted electrical box. This work constitutes an experimental, initial phase of method evaluation.

ARC evaluators (Test Engineer and DOE Fellows) were present at all times for the duration of the technology demonstrations to record performance data, take photographs and capture videos during the technology's operation. A detailed technology demonstration test plan [3] was developed for this technology evaluation. During the demonstration, ARC evaluators gathered data concerning the technology's operation, performance, maintenance, health and safety aspects, cost, benefits, and limitations, and the ability of the technology to be decontaminated. Data tables [3] were prepared containing a list of specific data that was collected and evaluated. In addition, a hardcover laboratory notebook was utilized to document the technology demonstration/evaluation along with digital photos and videos.

The technology vendor was responsible for providing operators for the technology equipment. The same operators were available throughout the duration of the demonstration to ensure continuity of operation and consistency of comments and feedback. The vendor was responsible for fuel, maintenance, and operation of the technology equipment.

The testing protocol included the following:

1. Trial-runs of the ICM climber into and through the hot cell mockup from the side entry point to gain familiarity with the mockup design by the operators, to ascertain that the technology could remotely gain entry into the hot cell mockup, and to determine how much of the hot cell interior was accessible to the technology. This trial run was also used to work out any logistical requirements of the technology (e.g., how to handle trailing electrical cords, objects inside hot cell – 50-gallon waste drum, work table, electrical box with ½-inch conduit mounted on one wall). In addition, a setup area was installed by the side entry point. This setup area acted as the buffer zone between "clean" and "contaminated" areas. The buffer area consisted of a radiological tent.

2. Testing of the spraying mechanism outside of the hot cell mockup. The fixative was prepared according to the manufacturer technical data and application instructions.

3. Demonstration of the technology utilizing the custom fixative spraying attachment in the hot cell mockup. This demonstration was performed from the side entry point and performance was evaluated as per FIU's test plan [3]. The surfaces sprayed included 3 walls (excluding the entry point wall), the ceiling and the floor surface within the hot cell mockup. Table 1 describes the surfaces sprayed and Figure 1 provides 3-dimension diagrams of the hot cell mock-up design.

Table 1. Hot Cell Mockup Surfaces Sprayed With Fixatives

Surface	Description	Dimensions	Number of Fixative Coatings
Wall A	Pre-existing long wall	10’ x 20’	2 coats
Wall B	Pre-existing short wall	10’ x 10’	2 coats
Wall C	Newly constructed long wall with window	10’ x 20;	1 coat
Wall D	Newly constructed short wall with entry door	10’ x 10’	0 coats (cameras were mounted to this wall)
Floor	Pre-existing floor	10’ x 20’	1 coat
Ceiling	Pre-existing ceiling	10’ x 20’	1 to 2 coats

Figure 1. 3-dimension diagrams of the hot cell mockup facility design

4. At the conclusion of the technology demonstration, the equipment was taken apart and "decontaminated". This task was performed to document which parts are removable and what can not be reached for cleaning (decontamination).

    a. The need for equipment and personnel decontamination is highly field site – specific and requires consideration of the following factors:
        i. types of onsite contaminants
        ii. levels of contamination
        iii. personal protection levels utilized
        iv. work activities performed
        v. evaluation/testing parameters

    b. The test "decontamination" procedures were performed on all equipment and accessories that entered the hot cell mockup, as designated by the ARC Test Engineer.

    c. The decontamination consisted of the following:
        i. overall equipment clean up steps
        ii. equipment disassembly steps
        iii. equipment and accessories clean up
        iv. equipment's cable removal & clean up
        v. collection/disposal of waste and consumables
        vi. PPE disposal/cleanup
        vii. clean up material collection/disposal

TEST SITE DESCRIPTION

The Applied Research Center at FIU uses its state-of-the-art facilities to conduct research and development, testing, evaluation, and validation for new and innovative technologies to support DOE and industry. ARC's headquarters, laboratories, and technology demonstration facilities are part of FIU's Engineering Center, a 243,000-square-foot building that occupies 38 acres in Miami, FL. ARC facilities include numerous specialized laboratories and facilities, including the outdoor Technology Assessment Facility where the hot cell mockup was constructed for this demonstration (Figures 2 and 3). The technology demonstration was conducted under standard non-nuclear conditions.

ARC provided all utilities and services, such as water, power, phone, and sanitation services at the work location. Specifically, ARC provided the following for the technology demonstration:

1) Compressed air - 375 CFM at 110 PSI
2) Electric - 110 volts 20 amp service. Three separate breakers were provided to operate:
    a. Climber and control station
    b. Vacuum
    c. Sprayer
3) Trash disposal of items generated during demonstration

4) Collection and disposal of secondary waste generated by the technology
5) Receiving and shipping assistance of ICM technology and associated equipment (2 pallets)
6) Fixative for the demonstration, an adequate amount to coat the interior walls and floor of the hot cell mockup as delineated in the test plan

A hot cell mockup was built at the ARC's Technology Assessment Facility for this technology demonstration. The hot cell mockup facility is similar in size, construction materials, and points of access to those found around the DOE complex. The hot cell mockup is 10-ft wide x 20-ft long x 10-ft high and has an entry point at one end as well as a window in the side. Also, the mockup facility was constructed with two round port holes right above the window for future adaptation of a robotic manipulator. The mockup facility was also provided with a 500 cfm air fan providing 15 air exchanges per hour. In addition, two video cameras were installed inside the mockup facility for video collection during the demonstration. The walls were constructed from poured concrete and Plexiglas was subsequently installed over the window. Figure 2 shows the hot cell mockup facility right after construction. A temporary radiological "tent" made of yellow laminated PVC plastic was set up as a buffer area immediately adjacent to the side entry point (Figure 3). This served as the preparation/staging area as well as the division between "clean" and "contaminated" areas.

Figure 2. Hot cell mockup facility at FIU-ARC's outdoor Technology Assessment Facility

Figure 3. Hot cell mockup facility and yellow buffer zone tent

TECHNOLOGY DESCRIPTION

Potential technologies and technology providers (vendors) were researched via: (1) FIU D&D technology databases, (2) internet search, (3) subject matter experts, and (4) professional conferences and forums. International Climbing Machines (ICM) was selected for the initial technology demonstration based on their work experience in nuclear decontamination, technology capabilities, and previous technology demonstrations.

The ICM climbing machines are remotely controlled by an operator with a laptop computer, allowing the machine to access areas unsafe for manual D&D activities. For the purposes of this technology demonstration, ICM developed a coating application via a spray applicator. The following technology description of the climber, the technical specifications shown in Table 2, and Figure 4 were obtained from the ICM website at http://www.icm.cc [4].

ICM climbers are small, remote-controlled, easily deployable, lightweight climbing machines with big payload capabilities. The machines can climb walls, ceilings or rounded surfaces. The inherent benefit is the patented seal that allows these lightweight climbers to climb over surface obstacles, uneven surfaces and surface contours, making them unlike any other climber. The machines weigh approx 30 pounds yet have a pull off strength of over 225 pounds. Plus, the machines are reliable, robust and easy to operate. The climbers also have interchangeable attachments so the same climber can be used for an array of missions. Held to the surface by vacuum force, the machines adhere to essentially any hard surface: metal, concrete, brick, etc. The patented, highly flexible seal ensures the machine is securely adhered as it locomotes the machine over surface obstacles such as bolt heads, plates, weld seams or virtually any surface irregularity.

Table 2. ICM Climber Specifications [4]

Primary Materials of Construction:	Carbon fiber / advanced composites
Climbing Machine Weight:	30 lbs
Width of Climber:	24 inches
Length of Climber:	24 inches
Height of Climber:	8 inches
Rate of travel:	2.5 - 3 inches/second
Pull-Off Strength:	225 lbs
Power (Adhesion Vacuum):	24 Volt DC/110 Volt AC/15 amp
Power (Capture Vacuum):	220 Volt / 30 amp

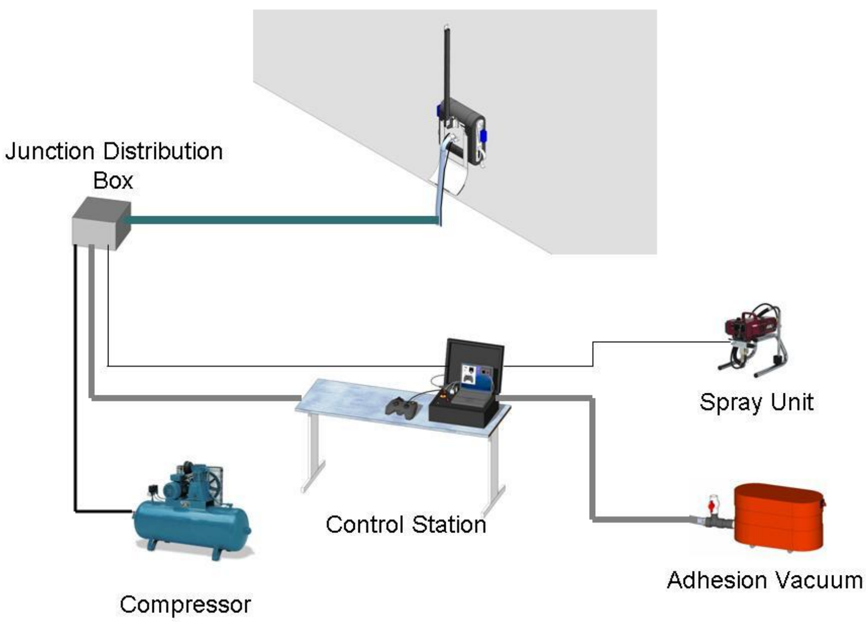

Figure 4. ICM climber set-up [2, 3]

RESULTS AND DISCUSSION

The technology demonstration was performed from November 11 to November 14, 2008. The technology vendor mobilized on November 11, sprayed fixative on November 11-13, and demobilized on November 14. The selected technology platform was expected to remotely enter a hot cell mockup facility and spray a fixative that would be capable of immobilizing loose/removable radioactive contamination. The field data tables are provided in Appendix A.

Trial-runs of the ICM climber into and through the hot cell mockup from the side entry point were first performed to gain familiarity by the operators, to ascertain that the technology can remotely gain entry into the hot cell mockup, and to determine how much of the hot cell interior is accessible to the technology. This trial run was also used to work out logistical requirements of the technology (e.g., how to handle trailing electrical cords, objects inside hot cell: 50-gallon drum, work table, mock electric box and cable, etc.). The climber had no difficulties in entering the hot cell mockup remotely from the adjacent radiation tent “buffer zone”, traveling around the drum and work table on the floor, transitioning onto the concrete walls, and climbing up the walls to the ceiling.

Prior to the demonstration, fixative products typically used inside hot cells were investigated for potential remote application [1]. The technology evaluation demonstrated the ability of the remote system to spray fixative products on horizontal and vertical concrete surfaces. Table 3 lists the fixatives used during the demonstration along with the surfaces and area coated with each. With the climbing machine positioned on the wall, the 4-foot boom attachment was capable of spraying the ceiling to a distance of 5-feet from the wall. The climbing machine also sprayed the top approximately 4 feet of the wall while positioned on the wall. From the floor, the climbing machine was then able to coat the lower 6-feet of wall as well as the floor surface.

Table 3. Fixatives Used During the Technology Demonstration

Product Manufacturer	Name of Product	Type of Product	Surfaces Coated	Surface Area Coated
Sherwin Williams	Promar 200	Latex paint	Ceiling, walls	294 sq ft
Sherwin Williams	Direct to metal (DTM)	100% acrylic coating	Ceiling, walls, floor	627 sq ft
Bartlett Services, Inc.	Polymeric Barrier System (PBS)	Non-toxic water-based solution which forms an impermeable barrier. Specifically for locking down loose contamination.	Ceiling, walls	108 sq ft

Table 4 below compares the fixative product coverage provided by the manufacturer to the actual coverage achieved during the technology demonstration. It should be noted that maximizing the coverage per gallon was not an objective of the demonstration. Instead, remotely achieving a coating capable of immobilizing radioactive contamination and minimizing missed or thinly coated surfaces was an overriding factor. The custom spraying attachment to the remote control climber was successful in achieving this goal. Figure 5 shows how excessive paint ran down the walls while spraying.

The coverage achieved by the Bartlett PBS (54 sq ft/gal) was very close to the coverage estimate provided by the manufacturer (50 sq ft/gal). A similar actual coverage was achieved with the Sherwin Williams DTM (57 sq ft/gal) and a slightly higher actual coverage was achieved with the Sherwin Williams Promar 200 (65 sq ft/gal). However, the coverage expected by the manufacturer was much higher for these 2 latter products: 155-170 sq ft/gal and 120-170 sq ft/gal, respectively. The reduction in actual coverage is likely due to the application of the products onto rough-surface concrete, rather than the typical application of DTM on metal and Promar 200 on wallboard.

Table 4. Coverage of Fixatives

Product	Coverage per Manufacturer	Surface Area Coated	Product Consumed	Actual Coverage
Promar 200	120-170 sq ft/gal	294 sq ft	4.5 gal	65 sq ft/gal
DTM	155-250 sq ft/gal	627 sq ft	11 gal	57 sq ft/gal
PBS	50 sq ft/gal	108 sq ft	2 gal	54 sq ft/gal

Figure 5. Excessive fixative running down wall during spraying

Table 5 provides a comparison of the spraying rate of the 3 fixative products used during the demonstration. The surface area coated with each product was divided by the total time that product was being sprayed to calculate the spraying rate. These spraying rates do not include break times and so illustrate the rate during active spraying. The rates do include the time required by the technology to position itself and climb the walls. Figure 6 shows the ICM climber as it began to spray Promar 200 to the hot cell mockup ceiling and Figure7 shows the climber spraying the wall with PBS.

Table 5. Spraying Production Rate Achieved During Demonstration

Product	Surface Area Coated	Total Spraying Time	Spraying Rate
Promar 200	294 sq ft	87 min	3.4 sq ft/min
DTM	627 sq ft	161 min	3.9 sq ft/min
PBS	108 sq ft	25 min	4.3 sq ft/min

Figure 6. ICM climber beginning to apply fixative (Promar 200) to hot cell mockup ceiling

Figure 7. PBS fixative being sprayed on hot cell mockup wall

At the conclusion of the demonstration and prior to demobilization, the equipment was taken apart to document which parts are removable and what can not be reached for cleaning/decontamination. Photographs were taken to document the cleaning/decontamination step (Appendix B). If used in a radioactively contaminated environment, the rollers and tracks would be cut off and disposed since the foam material is not conducive to decontamination. In addition, while the tether is protected by a sleeve of plastic, the adhesion vacuum hose would be internally contaminated and would also be disposed. The remaining cables and hoses in the tether (e.g., electronic input line, main air hose, and retrieval cable) could be wiped/ decontaminated as an alternative to disposing of the entire tether. The two climbing machine drive chains would be difficult to confirm as clean and would likely be disposed. The main body of the climber consists of a carbon fiber chassis, aluminum or resin drive shafts and spindles, a vacuum chamber, and an internal box for electronics. The body could be wiped/ decontaminated but may be difficult to free-release due to the difficulty in confirming that the contamination did not enter the climber through the openings for the drive shafts and spindles, air hose, etc.

CONCLUSIONS

Overall, the technology was capable of successfully achieving the objectives of this demonstration. It was able to remotely enter the hot cell mockup from the side entry door, travel across the floor and climb up the walls unassisted while being controlled remotely by the operator. The technology sprayed coatings of 3 different types of fixatives to the wall, floor, and ceiling surfaces.

The technology was evaluated for 16 health and safety categories and a risk rating was applied to each. Twelve of the categories were either not applicable to this technology or received a risk rating of 1, hazard may be present but not expected over background levels. The remaining categories received a rating of 2, some level of hazard above background level known to be present. These categories included pressure hazards, tripping and falling (from the trailing tether), noise (from accessory equipment – vacuum, air compressor, and airless sprayer), and inhalation (from the product being sprayed).

The challenges encountered during the demonstration included tether management, maintaining line-of-sight between the operator and the technology, and clogging of the sprayer tip. The tether was provided additional slack and retracted by an assistant located in the adjacent radiation buffer tent. Close communication between this assistant and the operator was essential but sometimes difficult due to the distance and noise from the equipment (e.g., compressor, vacuum, and sprayer). One recommendation is to provide radio communication for the assistant and operator.

One window and 2 video cameras were used to allow the operator to view the technology during the demonstration. This worked well for the wall located opposite of the window and for the side wall where the climber and spraying boom could still be seen from the window. The video cameras were fixed on the entry door wall and had a small amount of remote zoom-tilt-pan capabilities. Still, it was more difficult to operate the climber/sprayer from the video images when the climber was out of line-of-sight from the window. Mobile cameras capable of being controlled remotely would be a tremendous benefit to the implementation of this technology.

Finally, the different products used acted differently during the demonstration. The Promar 200 seemed to dry faster and while it sprayed easily for the first hour to hour-and-a-half of use, it then proceeded to clog the sprayer tip repeatedly. No clogging issues were encountered with either the DTM or the PBS. It is recommended that any fixative product be tested thoroughly with the equipment prior to being used in a radioactive environment. In addition, it is recommended that different types of spray nozzles be tested.

The results of this demonstration, including this technology demonstration report and additional photographs and videos taken during the demonstration will be made available to the general D&D community through the FIU/DOE D&D Knowledge Management Information Tool located on the web at www.dndkm.org.

REFERENCES

[1] SRS ALARA Center, "November 2007 Activity Report," November 2007.

[2] AEA Technology Engineering Services, Inc., "*ORNL Remote Operations for D&D Activities Final Report*," March 2007.

[3] Applied Research Center, "*Fixative Sprayer Platform: Technology Demonstration Test Plan"* Miami, Florida, November, 2008.

[4] International Climbing Machine. Retrieved August 27, 2008 from ICM website: http://www.icm.cc/.

APPENDIX A.
FIELD DATA TABLES

FIXATIVE SPRAYER PLATFORM TECHNOLOGIES

Field Data Tables

DATA	DESCRIPTION	UNITS
The following sections can be completed prior to the demonstration:		
GENERAL INFORMATION ABOUT TECHNOLOGY **To be supplied by the vendor.**		
Technology Name	The generic name of the technology (i.e., remote climbing machine)	No units
	Remote control climbing machine fixative sprayer platform	
Technology Model Number	Unique identifier for the technology model, where applicable. Typically supplied by the manufacturer.	No units
	CM500	
Technology Model Description	Technical description of the technology including basic principle(s) and operational parameters and conditions. Discuss all pieces of equipment required by the original manufacturer for this technology model. Include dimensions, weight, and schematic of technology model.	No units
	The **<u>climbing machine</u>** has three main parts: the main body, the paint boom on the front end, and the transition bar on the back. The main body is responsible for locomotion, protection of vital electronics and control components, and for attaching to wall surfaces. The main body consists of a carbon fiber chassis, aluminum or resin drive shafts and spindles, a vacuum chamber and an internal box for electronics. The climbing machine rides on four rollers and two tracks. The transition bar allows the climbing machine to move from floor to wall. At the end of the transition bar is the umbilical support bar to support the umbilical components (air input hoses, adhesion vacuum hose, and electronic cable) and gives the machine room to maneuver. Dimensions: 36” x 24” x 18” Weight: 30 lbs The **<u>control station</u>** is used to monitor and control the machine movement and the operation of accessories. The control station includes the hand controller, a laptop computer with software, and the vacuum adhesion indicator. Dimensions: 18” x 14” x 24” Weight: 12 lbs The **<u>junction box</u>** supplies the climbing machine with operational air from the compressor and it sends command signals to the climber. It also sets the maximum pressures and has shutoff and filter features. The system is designed to run on source air that is	

DATA	DESCRIPTION	UNITS
	a maximum of 115 psi. Two regulators control the pressure of air flowing to the rest of the system. Dimensions: 24” x 14” x 24” Weight: 12 lbs The **adhesion vacuum** provides the suction that holds the climbing machine in vertical or inverted positions. Dimensions: 24” x 13” x 24” Weight: 70 lbs The spray function of the climbing machine is provided by a Titan 440i **airless sprayer**. Dimensions: 18” x 15” x 18” H Weight: 32 lbs Schematics of each part of the system can be found in the ICM operations manual.	
Maturity of Technology	The maturity of the technology at the time of the demonstration. Choose from: • Commercially available • Prototype	No units
	Commercially available	
Utility Requirements for Technology model	Energy and material requirements. Includes compressed air and water requirements.	No units
	Climbing machine Power: 24 V DC <4 amp supply Air: 100 psi 20 scfm compressed air Control station Power: 24 V AC single phase 60 Hz 5 amp Junction box Power: 24 V DC <4 amp supply Air: 100 psi 20 scfm compressed air	

FIXATIVE SPRAYER PLATFORM TECHNOLOGIES

Field Data Tables

DATA	DESCRIPTION	UNITS
	Adhesion vacuum Power: 110 V, 1 phase, 60 Hz, 2 HP, 16 amp Airless sprayer Power: 120V 15 amp minimum	
Technology Model Capital Costs (Rental and Service also)	The vendor's current list price for the entire technology model. Include cost of all pieces that are part of the technology model. Include current prices for rental of equipment or as service provider.	$
	Sale - $130K Rental - $15K/mo Service - $200K	
Useful Life Expectancy	The number of hours that the technology model can possibly be used for its specified purpose.	Hrs
	Thousands of hours barring any misuse	
Applicable Media	List all possible surface types to which the technology model can be applied.	No units
	Anything non-porous, including wood, metal (ferrous and non-ferrous), plastic, concrete, brick, block, glass, etc.	
Applicable Geometries	List all possible surface geometries to which the technology model can be applied.	No units
	Any reasonably sized geometry including flat, sphere, cylinder, etc. Reasonable size includes geometries of 4' radius and up, although the technology could be scaled down for smaller geometries.	
Equipment portability	Select one or more ways that are ways for removing the technology model from the transportation vehicle once it arrives at the facility where the demonstration is to be performed. Options include: • 1 person needed – the technology model is small/light and easily carried by one person • 2 people needed – the technology model is not as small/light and requires two people to carry • Forklift needed – the technology model is large/heavy and requires a forklift to remove it from the vehicle • Truck/trailer mounted – the major pieces of the technology model are not removed from the truck/trailer	No units

FIXATIVE SPRAYER PLATFORM TECHNOLOGIES

Field Data Tables

DATA	DESCRIPTION	UNITS
	but instead are operated from this location	
	1 person	
Fixative Cost per Unit	Type of fixative used by the technology model for the demonstration and its cost per unit.	$/User Defined
	Sherwin Williams Promar 200 - $26/gallon Sherwin Williams DTM - $32/gallon Bartlett PBS - $47/gallon	
Required Personnel for Operation	Manpower requirements for operation of this technology. Distinguish between number of equipment operators and number of technicians required.	No units
	1 operator and 1 technician/assistant	
Level of training required	The level of training and the skills that are supposed to be provided to the operators of the technology.	No units
	5-day training course	
Technology Availability	Average expected delay between order placement and vendor delivery.	No units
	6 weeks	
Scale-up Requirements	Provide a description of what enhancements (equipment/personnel/procedures) would be changed or added by the vendor if the size of the job was greater.	No units
	Technology itself wouldn't be scaled up (the climber size would not increase) but more units and personnel would be added to meet the need of time constraints.	
Maintenance Requirements	Listing of the maintenance requirements for the technology model. Include time frames to perform maintenance. Examples include: • change filter every 6 months • add oil motor at end of every day	No units

DATA	DESCRIPTION	UNITS
	• apply talc to climber rollers with each use • replace tracks and rollers when damaged, frequency depends on severity of use • add oil to sprayer with each use • change filter on junction box periodically • no maintenance needed for vacuum or control station	
Total Maintenance Cost	Include total cost of regular maintenance per hour of use.	$/hr
	Minimal	
Technology Support Equipment and Cost for Each Unit	List any required support equipment (not utilities) that are included in the demonstration. Include description of each and associated capital costs.	$
	Vacuum – Ruwac model WS1000SA, intermittent duty vacuum. Airless sprayer – Titan 440i airless sprayer. $800 Air compressor – 375 cfm,150 psi air compressor from Sunbelt Rentals	
Consumables and Cost for Each Unit	List additional expendable items and associated costs for each item, used with the technology that are typically discarded at the end of a job. Examples include vacuum hoses, belts, etc.	$
	No items are typically discarded at the end of a job from this technology. However, expected expendables when the technology is used in a radioactively contaminated environment include the follows: • Foam tracks and rollers • Drive chains • Air motor behind gear • Vacuum • Vacuum hose and tether Total estimate for replacement of contaminated items would be $15-20K.	

MANUFACTURER INFORMATION		
DATA	**DESCRIPTION**	**UNITS**
Name and Address	Information to be collected about company that manufactured the technology model.	No units
	International Climbing Machines, Inc. 630 Elmira Road Ithaca, NY 14850	
Phone Number(s)	Include area code. Include pager number or second phone number (if applicable).	No units
	(607) 288-4001	
Fax Number	Manufacturer's fax number including area code.	No units
	(607) 288-4004	
Website	Internet web-site location for manufacturer (if applicable).	No units
	www.icm.cc	
E-Mail	E-mail address for the manufacturer where other D&D professionals can request information.	No units
	sam@icm.cc	
Services Available	What services the manufacturer provides. Chosen from one of the following: Service provider, Sells technology model*, Rents technology model* (* When these items are chosen, if the manufacturer will train site personnel, include technology model training time.)	No units
	Any service required to perform the work. Includes service provider, sells technology model, and rents technology model. 5-day training available when selling or renting.	
References	Locations where this technology model has been used previously (especially other DOE or commercial	No units

	nuclear facilities).	
	Exelon Quad Cities Oconee Nuclear Plant Atomic Energy of Canada Boeing Department of Defense Quest Integrated (QI2) in Seattle Demonstration at Hanford, Savannah River Site, Idaho National Lab, and FIU.	
Publications	List of brochures or publications that provide additional information about the technology model and/or the company. Corporate history or profile.	No units
	ICM was incorporated in April of 2000 as a focused R&D effort developing small, remote-controlled devices which could climb vertical surfaces, particularly surfaces with boltheads, weld seams, plates and other obstructions commonly found in “real life” field conditions. With the assistance from three government grants, founder and investor capital, ICM embarked upon a saga of intense exploration. The result: the technology has flourished into its current market-ready climbing machine. Refer to the website for additional information and case histories: www.icm.cc	
Photographs/Video	If photographs or video is received from the manufacturer and sent for inclusion in the database, list which and the number of each sent to FIU.	No units
	Photographs and videos from FIU demos.	
VENDOR INFORMATION		
Name and Address	Information to be collected about the company that was chosen as the vendor for this particular demonstration.	No units

	International Climbing Machines, Inc. 630 Elmira Road Ithaca, NY 14850	
Phone Number(s)	Include area code. Include pager number or second phone number (if applicable).	No units
	(607) 288-4001	
Fax Number	Vendor’s fax number including area code.	No units
	(607) 288-4004	
Website	Internet web-site location for vendor (if applicable).	No units
	www.icm.cc	
E-Mail	E-mail address for the vendor where other D&D professionals can request information.	No units
	sam@icm.cc	
Services Available	What services the vendor provides. Chosen from one of the following: • Service provider Sells technology model * Rents technology model * (* When these items are chosen, if the manufacturer will train site personnel, include technology model training time.)	No units
	Any service required to perform the work. Includes service provider, sells technology model, and rents technology model. 5-day training available when selling or renting.	
References	List of locations where this technology model has been used previously (especially other DOE or commercial nuclear facilities).	No units
	Exelon Quad Cities Oconee Nuclear Plant Atomic Energy of Canada Boing Department of Defense	

	Quest Integrated (QI2) in Seattle Demonstration at Hanford, Savannah River Site, Idaho National Lab, and FIU.	
Publications	List of brochures or publications that provide additional information about the technology and/or the company. Corporate history.	No units
	ICM was incorporated in April of 2000 as a focused R&D effort developing small, remote-controlled devices which could climb vertical surfaces, particularly surfaces with boltheads, weld seams, plates and other obstructions commonly found in “real life” field conditions. With the assistance from three government grants, founder and investor capital, ICM embarked upon a saga of intense exploration. The result: the technology has flourished into its current market-ready climbing machine. Refer to the website for additional information and case histories: www.icm.cc	

GENERAL DEMONSTRATION INFORMATION (To be completed by evaluation team)		
DATA	**DESCRIPTION**	**UNITS**
Demonstration Site Location and Description	Location of demonstration including name of facility and city/state. Example includes: FIU ARC, Miami, FL Also, give brief demonstration site description.	No units
	FIU ARC, Miami, FL Hot cell mock-up was built at the outdoor technology assessment facility at the Applied Research Center of Florida International University. The hot cell design represents a typical DOE site facility in size, construction materials, and points of access. The hot cell mock-up is 10' wide, 20' long, and 10' high and has an entry point at one end as well as a window in the side. The construction is poured concrete and Plexiglas was installed over the window. A temporary tent made of yellow laminated PVC plastic was set up as a buffer area immediately adjacent to the side entry.	
Problem Targeted	A brief description of the specific problem(s) targeted and its importance or critical nature.	No units
	Many facilities slated for D&D across the DOE complex pose hazards (radiological, chemical, and structural) which prevent the use of traditional manual techniques. Efficient and safe D&D of the facilities will require the use of remotely operated technologies. In addition, the D&D of a hot cell facility requires that each of the hot cells be cleaned and stabilized to allow demolition to occur while maintaining worker radiation exposure ALARA and without spreading radioactive contamination. Dozens of hot cell facilities across the DOE complex, containing hundreds of highly contaminated hot cells, will require safe and effective D&D. One decontamination step typically consists of applying a fixative coating (or similar material) to all hot cell surfaces to hold contamination in place during hot cell demolition. A study on available remote technologies for D&D activities, performed by Florida International University (FIU) and NuVision Engineering, indicated that there was no remotely operated technology available to meet the need for the remote application of strippable/fixative coatings (ORNL Remote Operations for D&D Activities, March 2007). This gap between the identified needs and the available technologies is especially critical for hot cell facilities, where access is typically very limited and radioactive contamination and dose rates are high.	
Demonstration Start and End Dates	Dates from start to finish for this particular demonstration. Example: October 20-24, 2008	No units
	November 11 – 14, 2008	
Major Objectives of the	Objectives as they relate to DOE environmental requirements.	No units

FIXATIVE SPRAYER PLATFORM TECHNOLOGIES

Field Data Tables

Demonstration	To meet the technology gap challenge for a technology to remotely apply strippable/fixative coatings to immobilize loose/removable contamination.

Major Elements of the Demonstration	Specific operations evaluated during the demonstration.	No units
	1. Technology’s ability to remotely enter and maneuver inside hot cell 2. Ability of technology to spray floor, walls, and ceiling 3. Effectiveness of spraying mechanism 4. Ability of technology to transition from horizontal to vertical surfaces 5. Ability of technology to be decontaminated	
Boundaries of the Demonstration	Specific goals addressed versus not addressed.	No units
	Entry wall was not sprayed/coated. This wall is where the cameras were mounted to capture video of the demonstration. Similarly, the lights mounted to the center of the ceiling, the exhaust fan, and the Plexiglas window were not sprayed/coated.	
Testing Organization, Contact Name, Phone Number, and E-Mail	• The name of the organization responsible for this demonstration and the information on a contact person who can be reached to gather additional information about all of the demonstrations performed by that organization. Example: FIU ARC, Leo Lagos, phone number, email	No units
	FIU ARC, Leo Lagos, 305-348-1810, lagosl@fiu.edu	
Test Engineer Name	The name of the person from the test organization in charge of setting up and evaluating this particular demonstration.	No units
	Peggy Shoffner	
Vendor Principal Investigator Name	The name of the vendor personnel that is supervising the demonstration from the demonstration site.	No units
	Sam Maggio and Mike Deschamps	

REGULATORY, PERMITTING, AND SAFETY ISSUES

DATA	DESCRIPTION	UNITS
Patent/licensing Issues	Is the technology patented or licensed. If so, by whom. Technology specific.	No units
	U.S. patent and international patent held by ICM.	
Site-specific Regulatory/Permitting Issues	List any regulatory/permitting issues specific to the demonstration site or state. Include any OSHA regulations that should be considered for technology operation.	No units
	Standard industrial/jobsite safety practices.	
Secondary Waste Stream Regulatory Considerations	List any regulations that must be considered for the collection and disposal of the secondary waste. Consider RCRA, DOT, and Waste Acceptance Criteria concerns.	No units
	No waste regulations need to be considered for the crawler technology itself. The spraying mechanism generates a secondary waste from flushing the line and spray nozzle with water. This waste is a mixture of water and the coating/fixative being sprayed. RCRA, DOT, and waste acceptance criteria concerns will depend on the fixative/coating product chosen.	
CERCLA Criteria	Evaluate the technology against the nine CERCLA evaluation criteria. (Even if CERCLA does not apply.) – See page 8 of ITSR Guidance (May 1998)	No units
	1. Overall protection of human health and the environment • Worker risk reduction - protects workers by performing D&D activity remotely. Dose rates within hot cells can range up to hundreds of R/hr, precluding human entry. • Environment risk reduction - fixes loose/removable contamination which will reduce radiation exposure and reduce risk of spread of contamination. 2. Compliance with ARARs 3. Long-term effectiveness and permanence N/A. Fixative coating is intended to be a short-term treatment prior to D&D. 4. Reduction of toxicity, mobility, or volume through treatment • Effective reduction of mobility by fixing loose/removable contamination. 5. Short-term effectiveness	

	• Excellent short-term effectiveness 6. Implementability • Technology is commercially available and able to be implemented. 7. Cost • Costs relatively low compared to other remote technologies. 8. State acceptance • No hurdles to state acceptance 9. Community acceptance • No hurdles to community acceptance	
Worker Safety Issues	Discuss any safety issues for the workers, include possible exposures or liability risks.	No units
	The technology actually mitigates safety issues for the workers by minimizing exposure to radioactivity; the technology can enter the area remotely and spray a coating to fix loose contamination.	
Community Safety/Stakeholder Issues	Discuss safety from the perspective of the community and stakeholders. Are there any stakeholder issues that might preclude the use of this technology at the site?	No units
	No stakeholder issues.	

DATA	DESCRIPTION	UNITS
The following sections are to be completed during or immediately after demonstration:		
DEMONSTRATION STATISTICS		
Information to be completed one time during demonstration:		
Mobilization Time	A measured time for how long it takes to mobilize the technology model prior to performing work. This time measures from the time the vendor arrives at the demonstration site to when the technology model is ready to operate.	hr
	50 min	
Portability Option Chosen	List of equipment/ personnel used at this particular demonstration to remove the technology model from the vendor vehicle during mobilization/demobilization.	No units
	2 pallets of equipment were brought to the demonstration site with a forklift. All equipment and supplies were removed from the pallets and set up by hand by 2 people. No heavy equipment is required once delivered.	
Required PPE for Demonstration	List the PPE that was required to operate the technology model during the demonstration. If the equipment operator and technicians wore different levels of PPE, describe the most restrictive.	No units
	Operator – no PPE required Technician/assistant – hearing protection (ear plugs), safety glasses and dust mask if entering area during spraying	
Demobilization Time	A measured time for how long it takes to demobilize the technology model after demonstration. This time measures from the time the technology model is ready to be decontaminated to when the vendor leaves the demonstration site.	hr
	1 hr 25min	
Supporting equipment installation/setup	A measure of time for setting up/hooking up supporting equipment (generator, air compressor, etc)	hr
	20 min	

FIXATIVE SPRAYER PLATFORM TECHNOLOGIES

Field Data Tables

DATA	DESCRIPTION	UNITS
Information to be completed for each problem set:		
Problem Set	Describe problem set for which data applies.	No units
	A typical hot cell in size, construction materials, and points of access (e.g., poured concrete walls, 10’ x 20’ x 10’ with an entry point at one end and a window in the side). Empty to moderate obstacles (table/bench, drum, mounted electrical box and conduit). Operator visual contact with technology is necessary, either via direct line-of-sight or remote video feed.	
Technology Model Maneuverability	Discuss maneuverability of the technology model, including horizontal and vertical surfaces. Include examples of ease or difficulty whenever possible.	No units
	Technology maneuvered easily on horizontal surfaces and transitioned routinely to vertical surfaces. Technology can move forwards, backwards, and turns. Technology requires 24” clearance (width) between obstacles to traverse surface and has the ability to push/move non-fixed obstacles on the floor. Technology had no difficulty with smooth poured concrete surfaces and with very rough (water-blasted) concrete surfaces.	
Spraying Parameters	Include measurements on the following: • Spraying rate (ft/min) and pressure (psi) • Width of spray coverage for each pass • Thickness of fixative coating on hot cell surfaces for each application • Amount of coating/fixative consumed • Amount of diesel/gas used by supporting equipment (gallons) Additional information should be collected if relevant.	Various
	• Spraying rate (ft/min): 3.4 to 4.3 sq ft/min • Pressure (psi): 1200 – 1400 psi • Width of spray coverage for each pass: 24” at 10” distance • Thickness of fixative coating on hot cell surfaces for each application: varied from 6 mils to 50 mils wet • Amount of coating/fixative consumed: 17.5 gal • Amount of diesel/gas used by supporting equipment (gallons): 35-gallons over 8 hours	

FIXATIVE SPRAYER PLATFORM TECHNOLOGIES

Field Data Tables

DATA	DESCRIPTION	UNITS
Observation of How Fixative is Applied	Describe the motion of the technology during the spraying process. • Is the technology driven on the hot cell surfaces at a constant rate? • Is the technology driven through the hot cell in steps, at each step allowing the technology to spray the fixative while stationary before further advancement? • Does the technology adheres to the surfaces (specially vertical surfaces)	No units
	Technology has the ability to move across surfaces at a constant rate while spraying the fixative and can also stay stationary and move the boom as needed to thoroughly coat a surface before moving on. The technology uses a vacuum chamber to adhere to vertical surfaces and generally travels across horizontal surfaces without the vacuum.	
Spraying Rate	The measurement of sprayed surfaces (ft^2) divided by the total number of hours of equipment operation required to complete the task. Spraying rate includes only the time the equipment is in operation, and does not include time spent in site specific activities.	ft^2/hr
	3.4 to 4.3 sq ft/min, averaged 3.8 sq ft/min or 228 sq ft/hr	
Production rate	The measurement of sprayed surfaces (ft^2) divided by the total number of hours required to complete the task at a given site. Site-specific production time begins immediately following equipment mobilization and ends at problem set completion, just prior to equipment demobilization. Production time includes breaks taken by operators, equipment adjustments and maintenance, rigging equipment adjustments (when appropriate), and consultations with test site administrators. Site-specific time does not include extended operator breaks (such as meals), test interruptions resulting from inclement weather, or the time required to correct major equipment failure.	ft^2/hr
	94 sq ft/hr	
Problems encountered	A detailed description of problems encountered during the demonstration.	No units

DATA	DESCRIPTION	UNITS
	The challenges encountered during the demonstration included tether management, maintaining line-of-sight between the operator and the technology, and clogging of the sprayer tip. The tether was provided additional slack and retracted by an assistant located in the adjacent radiation buffer tent. Close communication between this assistant and the operator was essential but sometimes difficult due to the distance and noise from the equipment (e.g., compressor, vacuum, and sprayer). One recommendation is to provide radio communication for the assistant and operator. Careful pre-planning is necessary to manage the tether when maneuvering around obstacles. The assistance occasionally entered the hot cell to move the tether when either additional pre-planning, or taking the time to maneuver the climber back toward the entry door and then re-approaching the desired surface would have precluded the need for personnel to enter. One window and 2 video cameras were used to allow the operator to view the technology during the demonstration. This worked well for the wall located opposite of the window and for the side wall where the climber and spraying boom could still be seen from the window. The video cameras were fixed on the entry door wall and had a small amount of remote zoom-tilt-pan capabilities. Still, it was more difficult to operate the climber/sprayer from the video images when the climber was out of line-of-sight from the window. Mobile cameras capable of being controlled remotely would be a tremendous benefit to the implementation of this technology. Finally, the different products used acted differently during the demonstration. The Promar 200 seemed to dry faster and while it sprayed easily for the first hour to hour-and-a-half of use, it then proceeded to clog the sprayer tip repeatedly. No clogging issues were encountered with either the DTM or the PBS as originally purchased. The DTM had a tint added to it on the third day of the demonstration to aid in seeing the coverage as it sprayed over the white hot cell surfaces. Thickened paint clumps and shreds of plastic were noted in the paint buckets after this tint was added and mixed; the sprayer tip again had clogging issues while using the tinted DTM. It is recommended that any fixative product be tested thoroughly with the equipment prior to being used in a radioactive environment.	
Quality of sprayed surfaces	Quality refers to the nature of the sprayed surfaces, whether they are evenly coated, whether there are surfaces the technology was unable to coat, etc.	No units

DATA	DESCRIPTION	UNITS
	Sprayed surfaces were unevenly coated and the fixatives tended to drip or pool with disproportionate spraying. The demonstration objectives prioritized the complete covering of the surfaces over leaving an even coat. The technology effectively sprayed both smooth poured concrete surfaces and very rough (water blasted) concrete surfaces. The ceiling, walls, and floor were all successfully coated.	
Application rate of fixative used	The quantity of fixative required per time of operation will be recorded at the test site during the technology demonstration.	(gal/hr)
	3.8 gal/hr	
Waste Volume	The measured volume of primary/secondary waste generated during this particular demonstration with respect to the area of surface coated with fixative.	No units
	A total of 1029 sq ft of surface was coated. Approximately 29 gallons of paint/water mixture was generated during the demonstration and approximately 25 gallons of loose dry trash from the test site.	
Waste Characteristics	The description of primary/secondary waste generated during this particular demonstration.	No units
	29 gallons of paint/water mixture from purging the sprayer, spray nozzle, and tubing 25 gallons of loose dry trash consisted of paper towels used for cleanup, plastic sleeve from tether, and general demo site trash (plastic water bottles, etc.)	
Technology Model Decontamination Method	The method used to clean and decontaminate the technology model after the demonstration is completed. Examples include: • wiped with damp rags • could not be decontaminated • cleaned using soft media blasting equipment	No units

DATA	DESCRIPTION	UNITS
	• stainless steel construction makes for easy decontamination by wiping with damp rags.	
	Clean tap water was flushed through the sprayer, spray nozzle, and tubing. Climbing technology was disassembled to document which parts are removable and what can not be reached for cleaning (decontamination). If used in a radioactively contaminated environment, the rollers and tracks would be cut off and disposed since the foam material is not conducive to decontamination. In addition, while the tether is protected by a sleeve of plastic, the adhesion vacuum hose would be internally contaminated and would also be disposed. The remaining cables and hoses in the tether (e.g., electronic input line, main air hose, and retrieval cable) could be wiped/ decontaminated as an alternative to disposing of the entire tether. The two climbing machine drive chains would be difficult to confirm as clean and would likely be disposed. The main body of the climber consists of a carbon fiber chassis, aluminum or resin drive shafts and spindles, a vacuum chamber, and an internal box for electronics. The body could be wiped/ decontaminated but may be difficult to free-release due to the difficulty in confirming that the contamination did not enter the climber through the openings for the drive shafts and spindles, air hose, etc.	

OVERALL RATING OF TECHNOLOGY		
Effectiveness of Overall Technology	Qualitative evaluation of how the technology model, spraying mechanism, and fixative combination demonstrated achieved the desired effect. Scale of 1-4, with 4 being the highest. Include reason rating was given including whether final outcome of demonstration met site needs, and if not, what needs were not met.	No units
	4 – demonstration fully met the site needs	
Benefits	Technical and economic advantage(s) of the technology over competing technologies (e.g., lower cost, greater degree of cleanup, more stable waste form, increased safety).	No units
	As compared to manual spraying of fixative in a hot cell setting, the technology increases worker safety and improves ALARA.	
Limitations	Disadvantages or shortfalls the technologies has (e.g., conditions under which the technology shall not be used at this time). Include any outstanding design issues and/or problems that may have been encountered during the demonstration or post-demonstration. Include needs/recommendations for further development.	No units
	Line-of-sight or high-quality video feed is required between the technology and the operator. Careful planning and management of tether is also required. Having a second separate remote vehicle to carry a video camera and assist with tether management may be beneficial. It would be difficult for the technology to maneuver in a very cluttered setting as it needs 24” clearance in width to traverse. Careful testing of any product to be sprayed needs to be performed ahead of time to ensure that clogging of the spray nozzle will not be an issue.	
Potential Markets	Potential markets for the technology (both specific DOE applications/sites and non-DOE applications)	No units
	Aircraft, DOD, spraying hot cells, applying linings on tanks and vessels, inspection/characterization, decontamination, repairs, retrieval	
Data Sensitivities	Description of items that could affect the quality of the data collected. Examples may include:	No units

	• Vendor statement that the equipment/personnel used at the demonstration is not what would be used in routine decontamination jobs • Vendor statement that demonstration conditions were unlike what would be seen in normal jobs and adversely effected their performance as seen in the statistics • Information about data that was misplaced or unsure of accuracy.	
	• The hydroblasted ceiling was extremely rough as it had been used in previous decontamination demonstrations. • The initial fixative used was different from the one specified in the test plan and dried quickly in the spray nozzle, causing clogging. • Rinse water initially had grass/debris in it due to a deteriorated hose. This could potentially have added to the clogging problems.	
Recommendations for Improvement	Describe any recommendations that should be made to the vendor to improve the technology to make it more safe, efficient, and/or cost effective.	No units
	Add remote cameras (with pan-tilt-zoom capabilities) to a ROV to provide various viewpoints of the technology for easier operating.	

HEALTH AND SAFETY RATINGS		
A risk rating (from 1 to 4) for each health and safety category and a description of the specific hazards associated with this particular technology and/or demonstration. Use NA if not applicable to this technology. 1 = Hazard may be present but not expected over background levels 2 = Some level of hazard above background level known to be present 3 = High hazard potential 4 = Potential for imminent danger to life and health		
DATA	**DESCRIPTION**	**UNITS**
Electrical	1	No units
Fire/Explosion	1	No units
Confined Space Entry	NA	No units
Mechanical Hazards	1	No units
Pressure Hazards	2 – technology uses vacuum pressure to adhere to vertical wall surface, the machine weights approximately 30 lbs and has a pull off strength (when vacuum is being applied) of over 225 lbs	No units
Tripping and Falling	2 – technology requires a trailing tether which could pose a tripping hazard	No units

Moving Vehicles	NA	No units
Protruding Objects	1	No units
Overhead Lifts	NA	No units
Inhalation	2 – inhalation hazard is not applicable to the climber itself; the inhalation hazard for the climber as used as a fixative sprayer platform would depend on the product being sprayed	No units
Skin Absorption	1	No units
Heat Stress	NA	No units
Noise	2 – the climber itself operates with little noise but requires the use of an adhesion vacuum, air compressor, and an airless sprayer (when used as a fixative sprayer platform), all of which produce noise above background levels	No units
Cold Stress	NA	No units
Ergonomic Hazards	1	No units
Particulate Emissions	1	No units
Other (list)		No units

APPENDIX B.
FIXATIVE SPRAYER PLATFORM DISASSEMBLY

The following photographs were taken after the technology demonstration to document the disassembly of the fixative sprayer platform.